Modified Genetic Algorithm-based Robot Path Planning to Avoid Static Obstacles Collision

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In this paper, a modified Genetic Algorithm is presented for mobile robot path planning applications in a known environment. The algorithm provides the optimal path using the modified variable-length chromosomes study uses the fitness function, which calculates the path length of the chromosomes such that the large path lengths are eliminated. The proposed algorithm uses the 8-way movement robot instead of the conventionally adopted 4-way movement commonly used in such applications. The results obtained using the proposed modified Genetic Algorithm during the study are compared with other approaches of the Genetic Algorithm. The proposed algorithm shows improvement in the convergence speed, provides better flexibility, provides shorter path length, and reduces the total time.

Keywords: Genetic algorithm, collision-free path planning, path-length, fitness function.

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1 Introduction

Nowadays, Autonomous mobile robot has been popular topic among researchers. In this era, Mobile robot plays an important role in defense, medical, industry, services, space exploration, etc. Navigation and obstacle avoidance are the key aspects of a mobile robot. The shortest path length problem along with least time taken problem are one of the most active research areas in the field of mobile robotics[1][2]. Several methods have been proposed to solve this path planning problem. Classical methods like Dijkstra, Road map and Potential field methods etc. are less capable of handling unknown, partially known and dynamic environments in their basic formulation. They are computationally intensive and are completely dependent on the prior knowledge of the environment in order to create an optimal and feasible path [4][5]. The new approaches like Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Ant-colony Optimization (ACO), etc. are known to perform better. These approaches are more proficient in handling in unknown, partially known and dynamic environments[6][7].

Genetic algorithm is an optimization technique which imitates the Darwinian theory of survival of the fittest in nature. GA is widely used in areas like image processing, self-adaptation control, planning and design, industrial engineering, intelligent manufacturing systems, bioengineering, system engineering, artificial intelligence and multi-objective evolution [8][9]. Different approaches used for genetic algorithms is mentioned in Table1. The basic components common to almost all genetic algorithms are:

- A fitness function for optimization
- A population of chromosomes
- Selection of which chromosomes will reproduce
- Crossover to produce next generation of chromosomes
- Random mutation of chromosomes in new generation

Table1. Different approaches used for genetic algorithm.

Author	Approach	Description
Tuncer and Yildirim (2012)[3]	Initial Population Fitness Function Selection Crossover Mutation	Both randomly generated and feasible initial population. $F = \sum_{i=0}^{n-1} d(\mathrm{p(i)}, p(i+1)) \quad For\ feasible\ path$ $F = \sum_{i=0}^{n-1} d(p(i), \mathrm{p(i+1)}) + penalite \quad For\ infeasible\ path$ Rank based Selection Single point Crossover Modified Mutation
Alajlan et al.(2013)[12]	Initial Population Fitness Function Selection Crossover Mutation	Generate randomly the initial population (set of feasible paths) using the greedy approach based on Euclidean distance Path length Elitist Selection Modified Crossover Random mutation: The mutation is performed by randomly choosing a cell from the individual and trying to replace it with one of its neighboring cells of the grid map.

Zhang and Lixin (2016)[9]	Initial Population Fitness Function Selection Crossover Mutation	Random search $F= \sum_{i=0}^{n-1} \mathrm{CO} - \mathrm{COST}(V(i) - V(i+1)$ Roulette Wheel selection Same Adjacency Crossover Randomly select a node called mutation node from the route and generate a path from the mutation node to the termination node by a process similar to the chromosome initialization.
Lamini et al.(2018)[16]	Initial Population Fitness Function Selection Crossover Mutation	Fixed population size using directed acyclic graph(feasible path) $F(p) = \frac{1}{w_l l(p) + w_{s1} s_1(P) + w_{s2} s_2(P)}$ Elitist and Truncation Selection Modified Same Adjacency Crossover Modified Mutation

In the present work, a modified Genetic Algorithm for mobile robotics presented to avoid static obstacle collision and generate an optimal path.

2 Proposed Method

A modified Genetic Algorithm is presented to solve path planning for mobile robot in a known environment. In the grid-based environment shown in figure 1, each node is represented as a parameter. A complete set of nodes forms an individual. A new generation is formed after selecting the best parents from the population using the fitness function. In the modified algorithm, the modified genetic operator is used to find the best population.

2.1 Environment model

In the present research work, 2D known environment has been used where the details of the obstacles such as position, size, are known. Each position is in the form of (x, y). The map represents the free space, start node, goal node and obstacles position. The occupancy of the grid has two values: 0 for free space and 1 for obstacles.

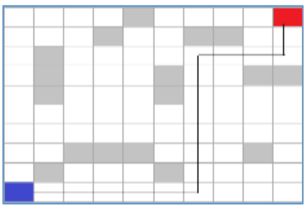


Fig.1. Grid based environment

2.2 Encoding of Chromosome& Initial Population

The initial population is encoded into the binary, octal, hexadecimal, and value-based forms. As shown in Fig. 2, a valid path consists of a sequence of grid labels that begins from starting node (X_o, Y_o) and ends at the goal node(X_n ,Y_n).In the modified Genetic Algorithm, the population is randomly generated so that the size of the population will affect the convergence speed of the algorithm[10][11]. In the present approach, the method used for creation of an initial population of variable size is adopted. The length of the chromosome is variable as shown in fig2. The model is grid-based and generates feasible paths that will constitute the initial population of GA.

Start point ↑ Goal ↑

X_0,Y_0	X_1,Y_1	X_2,Y_2	- - -	- - - -	- - - -	X_n,Y_n

Fig.2. Initial Population chromosome

2.3 Fitness Function

Once the initial population is created, the performance of each individual is determined using the fitness function. The quality of genetic algorithm path planning is directly related to the fitness value. It will provide convergence speed and stability to Genetic algorithm [14].The path length is the primary criteria for the fitness function.

$$F(p) = \frac{1}{l_p} \quad (1)$$

Where:
F(p)= fitness value of the population
lp = path length, this value is calculated using the Euclidean distance.

In the proposed approach, if the length of path is large then the fitness value is small, so that the lowest the fitness value, chances of selection of that population is high.

2.4 Selection

Selection is the most important step where determine a particular string of population is participate in the reproduction process or not. There are different selection methods that can be used Elitism Selection, Tournament Selection (TOS), Roulette Wheel Selection (RWS), Stochastic Universal Sampling (SUS), Linear Rank Selection (LRS), Exponential Rank Selection (ERS), and the Truncation Selection (TRS)[9].In our approach, roulette wheel selection is used, where the random rotation of the wheel to select for specific solutions that will participate information of the next generation.

2.5 Crossover

After selecting individuals using the selection operator then perform crossover operation. The crossover point is randomly selected from the parent chromosome. The limits are chosen in order to keep the start and goal point without change during the crossover process [9][15]. For example two parents are as following, they will be crossover at the position (X_{15} , Y_{16}) :-

X_0,Y_0	X_4,Y_3	X_4,Y_{10}	X_{15},Y_{16}	X_{29},Y_{16}	X_{29},Y_{29}

X_0,Y_0	X_6,Y_0	X_6,Y_{15}	X_{15},Y_{16}	X_{19},Y_{15}	X_{29},Y_{19}	X_{29},Y_{29}

The new two children are:

X_0,Y_0	X_6,Y_0	X_6,Y_{15}	X_{15},Y_{16}	X_{29},Y_{16}	X_{29},Y_{29}

X_0,Y_0	X_4,Y_3	X_4,Y_{10}	X_{15},Y_{16}	X_{19},Y_{15}	X_{29},Y_{19}	X_{29},Y_{29}

2.6 Mutation

In the Mutation operator, the gene of the chromosome mutates to create new offspring (children). The place is randomly chosen from the string of the chromosome and displaced such that the resulting solution is valid [10][13].

The framework used in proposed algorithm is 8-way movement instead of the conventional 4 -way movement.

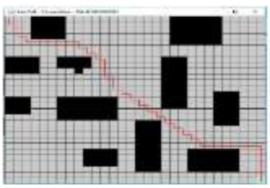
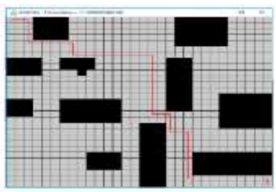
3 Pseudo code of the proposed Genetic Algorithm-

- BEGIN
  - Generate the 2D grid map
  - Initialize the start and goal point and obstacle position
  - Generate randomly initial population
  - WHILE NOT (converge condition met) DO
    - Evaluate the fitness function of each chromosome
    - Rank the population using fitness value (lowest fitness has higher rank)
    - Apply crossover between two parents, while without changing the start and goal
    - Apply the mutation operator
  - END
  - Output the best chromosome
- END

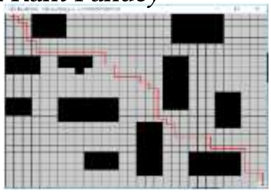
4 Simulation Results

The simulation results of the modified Genetic Algorithm to avoid static obstacle collision for mobile robot are presented using a grid size (30x30) cell. Different approaches used for finding the optimal solution using genetic algorithm [3] [9] [12] [16] are compared with the present work is shown in Table 2 and the results of path lengths & No. of direction changes of proposed method and differents approaches shown in Table 3.

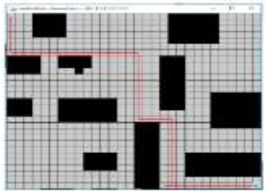
Table 2. Optimal Path found by the different methods.

Approaches	Result
Tuncer and Yildirim (2012) [3]	
Alajlan et al. (2013) [12]	

Zhang and Lixin (2016) [9]



Lamini et al. (2018) [16]



Proposed Method

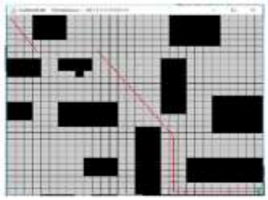


Table 3. The results of Path length & No. of direction changes of proposed method and different approaches.

Approach	Path length	No. of changes of direction
Tuncer and Yildirim (2012) [3]	58.2426	36
Alajlan et al. (2013) [12]	58.0	11
Zhang and Lixin (2016) [9]	57.414	25
Lamini et al. (2018) [16]	54.948	6
Proposed Method	51.529	4

5 Conclusion

This paper present a static path planning method for mobile robots based on improved Genetic algorithm. In this paper, the modified Genetic Algorithm has been presented to provide an optimal path using the modified variable length chromosome. The fitness function used in the study calculates the path length of the chromosomes by eliminating large path lengths. The method accepts the node according to the fitness value of total path instead of the direction of movement through the mutated node. The proposed algorithm uses 8-way movement robot leading to improvement in the convergence speed, provide better flexibility, provide shorter path length and reduces the total time and the effectiveness of the algorithm is verified. Advantages of modified genetic algorithm can be applied to variety of applications. It is expected to generate next paper on moving Obstacles by using any other meta-heuristic technique.

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